Predictions of Total Work Based on Measures of Muscle Strength and Hop Performance in Individuals after ACL Reconstruction

Honors Research Thesis
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Abstract

A tear to the anterior cruciate ligament (ACL) is a devastating injury that commonly results in ACL reconstruction (ACLR) and can have detrimental effects on an individual's activity level, extracurricular participation and future joint health. Muscle strength and hop performance are common clinical tools to evaluate readiness for return to sports participation, but limited information is known regarding how these measures relate to specific measures of athletic performance. The purpose of this study was to determine the association between measures of hop performance and muscle strength with total work during a single leg vertical jump task in young athletes after ACLR. Total work was used to quantify cumulative power during a single leg vertical jump. Fifty-one individuals (36 females, age 14-23) with unilateral ACLR, who were cleared by a physician to return to their sport following ACLR and rehabilitation, participated in the study. Participants performed a repeated single leg vertical jump for 10 seconds on a force plate, which measured power generation and absorption during each single-limb takeoff and landing. Total work (J) was calculated by summing the area under the positive and negative power curve. Clinical data gathered included performance on a 6-meter timed hop (seconds), single hop, triple hop and crossover hop for distance (cm). Quadriceps femoris and hamstring strength (Nm) were calculated with an isokinetic dynamometer using isokinetic (180°/s, 300°/s) and isometric testing. Through regression analysis, nearly all clinical measures significantly predicted variance in power output during the vertical jump task. Quadriceps femoris strength at 180°/s was the strongest predictor (highest R^2 adjusted value) of total work for both the involved and uninvolved limb after accounting for height and weight. Future research is needed to understand the association between performance on the repeated

vertical single leg jump test and sport performance after ACLR to better predict a successful return to sport.

Introduction

A tear to the anterior cruciate ligament (ACL) is a common and devastating injury that can have detrimental effects on activity and sport participation in young athletes. ACL injuries most commonly occur in athletes and those who are physically active. Overall incidence of ACL injuries is estimated at approximately 200,000 annually (Brown & Carson, 1999). The highest incidence of ACL injury is seen in adolescents playing sports that involve a pivoting movement such as football, soccer and basketball (Lohmander, Englund, Dahl, & Roos, 2007).

ACL injury can cause functional impairment and future joint deterioration along with an increased risk for future ACL injury (Paterno et al., 2010; Schmitt, Paterno, & Hewett, 2012). Athletes with an ACL injury commonly undergo ACL reconstruction (ACLR) surgery to return to a high level of function. However, recent studies have reported that young individuals who return to high-level activity following ACLR are at high-risk for poor outcome (Schmitt et al., 2012), given the high risk of second ACL injury (Paterno et al., 2010) and given only moderate return to sport rates (Ardern, Webster, Taylor, & Feller, 2011).

Common clinical measures that determine readiness for return to sport after ACLR, suggested in literature, involve an emphasis on identifying deficits shown by the athlete (Aune, Holm, Risberg, Jensen, & Steen, 2001). Factors known to impact an athlete's return to sport and overall performance include muscle strength and hop test performance (Thomee et al., 2012). According to Thomee et al., restored lower extremity muscle function, such as knee extensor and flexor muscle strength and one-legged jumping ability, is highly valued after ACL injury in order to safely return to sports or physical activity (Thomee et al., 2012). In an additional study, the vertical jump test was found to be a good tool to assess functional profile of patients and to develop standards for the evaluation of lower extremity strength and power (Petschnig, Baron, & Albrecht, 1998). The ability to express high power outputs is considered to be one of the fundamental characteristics underlying successful performance in an array of sporting activities such as jumping, throwing, and changing direction (Haff & Nimphius, 2012).

The goal of rehabilitation following ACLR is to prepare the athlete to return to their maximal level of function. However, lingering impairments are often cited as a limiting factor in an athlete's return to preinjury levels of function (Schmitt et al., 2012). In a study conducted by Paterno et al., vertical ground reaction force (VGRF) and loading rate during a drop landing task were measured and detected altered landing patterns in patients who had undergone ACLR compared with controls (Paterno, Ford, Myer, Heyl, & Hewett, 2007). Further, the one-legged vertical jump test is capable of detecting functional limitations of the lower limb following knee ligament reconstruction up to 54 weeks postoperatively (Petschnig et al., 1998). Many jumps and most propulsive forces such as running and agility are generated in a unilateral fashion (Meylan et al., 2009). For this reason, unilateral assessment is advantageous for means of reproducing uncompensated movement patterns. The repeated maximal vertical single leg hop test is a vigorous test appropriate for the athletic population to evaluate an athlete's level of function and performance during demanding activity. The repeated maximal vertical single leg hop test requires the athlete to complete maximal jumps for height in an extended period of time versus the hop tests which requires athletes to complete fewer and controlled jumps without a time parameter. However, the specific criteria patients need to achieve to promote likelihood for successful return to sport varies widely and is not always empirically based.

Additionally, further research is needed to assess the relationships between currently used functional tests. Power is a measure of force and distance at a point in time. In order to assess power over a longer period of time, total work, a cumulative measure of power, is used. Little is known about the total work generated during a repeated hop test compared to the more commonly reported measures of hop test performance and lower limb muscle strength. The purpose of this study was investigate which variables, such as measures of lower limb strength or distance during hop tests, best correlated with total work during performances of repeated single leg vertical jump tests in young athletes following ACLR at the time of return to sport. The hypothesis was that both the hop tests results and measures of lower limb muscle strength would be statistically significant in predicting measures of total work. The second hypothesis tested was that hop tests results, when compared to measures of muscle strength, would better predict measures of total work. A clinical measure may be found that can predict athletes' performances on a demanding jumping test conducted in biomechanics research labs after a serious injury such as ACLR.

Materials and Methods

Sample

The participants in this study consisted of 51 athletes, including 36 females and 15 males, ranging in age from 14-23 with primary unilateral ACLR. Participants were tested when they were cleared to return to sport by their physical therapist and surgeon following ACLR surgery and rehabilitation. Participants in this study were part of a larger study conducted at Cincinnati Children's Hospital investigating outcomes after ACLR. Participants were recruited from local orthopedic practices, physical therapy clinics, and the community. The study protocol was approved by the Institutional Review Board of Cincinnati Children's Hospital Medical Center and participants/parents gave written consent to participate.

Tests

Repeated Maximal Vertical Single Leg Hop Test The participants completed repeated vertical single-leg hops (RVSHs) for 10 seconds to evaluate power generation and absorption patterns. During RVSHs, athletes were instructed to jump as high as they could, land under control, recover their balance and repeat the hopping for 10 seconds on a force plate. Following verbal instruction and practice, one successful test trial was recorded for the involved and uninvolved lower extremity. Faulty test trials were determined when the athlete placed the contralateral foot onto the force place or landed outside the dimensions of the force plate. If a faulty trial was performed, the trial was stopped and then discarded.

Power curves were generated from the RVSHs in order to determine work. The power curves were then evaluated for each athlete and the highest jump was determined. The height of the jump was determined by the time off the ground. The static flat segment of the force curve represents the time the athlete was not in contact with the force plate, or the time the athlete spent in the air. The longer this segment, the more time the athlete spent in the air and the higher the athlete jumped. The custom Matlab code identified the highest jump for each athlete. The highest jump was chosen to standardize the jump evaluated for all participants. If the highest jump was determined as not representative of all jumps, the analysis program identified the next highest jump performed by the athlete. Upon determination of a representative jump, the work was calculated for that single jump. The total jump was measured from the point on the power curve that crossed 0 before the representative jump until the next point the power curve crossed 0 after the representative jump (Figure 1). The first point where the power curve crossed 0 meant that the athlete started to generate power in order to jump, which was detected by the force plate (Figure 1). The second point where the power curve crossed 0 meant that the athlete had completed power absorption after landing on the force plate (Figure 1). This eliminated any excess work that some athletes produced after the initial jump such as subsequent small jumps that generated additional power curves. The area under the curve was the calculated work for each athlete for the representative jump (Figure 1). The total work was the sum of the positive work generated before the jump and negative work absorbed upon landing (Figure 1).

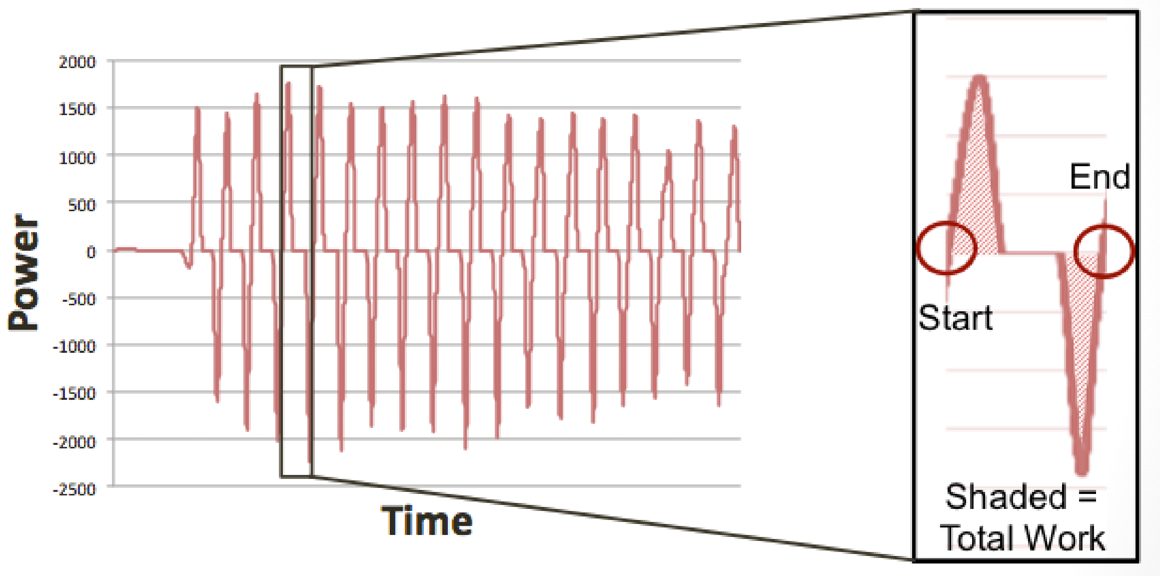

Figure 1: Sample power curve generated from the Repeated Vertical Single Leg Hop (RVSH) Test (left) & a representative jump (right) showing where the power curve crossed 0 (circles). The shaded area under the curve is the calculated total work.

Clinical Hop Tests Athletes also performed clinical single leg hop tests consisting of the single hop test (SHT), triple hop test (THT), and crossover hop test (CHT) all for distance (cm), as well as a 6 meter timed hop (TiHT) (s) (Figure 2), which are all commonly used clinical measures of performance following ACLR (Reid, Birmingham, Stratford, Alcock, & Giffin, 2007). Following two practice trials, participants completed two measurement trials for each limb, tested in random order. The averages of the two trials for the involved and uninvolved limbs were used for further analysis. For the three distance hop tests, the goal was to hop forward as far as possible, while maintaining a controlled landing. For the SHT, the participant started in a single-limb stance position on the test limb, moved into a semi-crouched position, utilized upper extremity swing and test-limb extension to propel forward, and hopped as far forward as possible to land on the same limb and maintain control of the landing without loss of balance or contralateral foot contact. For the THT, participants performed three consecutive maximal hops forward on the same limb using arm swing if desired. The distance was measured from the starting point to the point where the foot struck the ground upon completing the third hop. A test trial was repeated if the participant was unable to complete a triple hop without losing balance and contacting the ground with the opposite leg. For the CHT, participants stood on one leg, then hopped as far as possible forward 3 times while alternatively crossing over a 15 cm marked strip on the floor. The total distance hopped forward was recorded. For the hops for distance (single, triple and crossover) to be deemed successful, the landing must have been maintained for 2 seconds. An unsuccessful hop was classified by any of the following: touching the ground with the contralateral lower extremity or any upper extremity, loss of balance, or an additional hop on landing.

The TiHT measured the amount of time it took the participant to hop 6 meters on one leg. Subjects were instructed to complete this distance as fast as possible. A standard stopwatch was used to record time. The stopwatch was started when a subject's heel lifted from the starting position and was stopped the moment that the tested foot passed the finish line. Measurements were recorded to the nearest 10^{th} of a second.

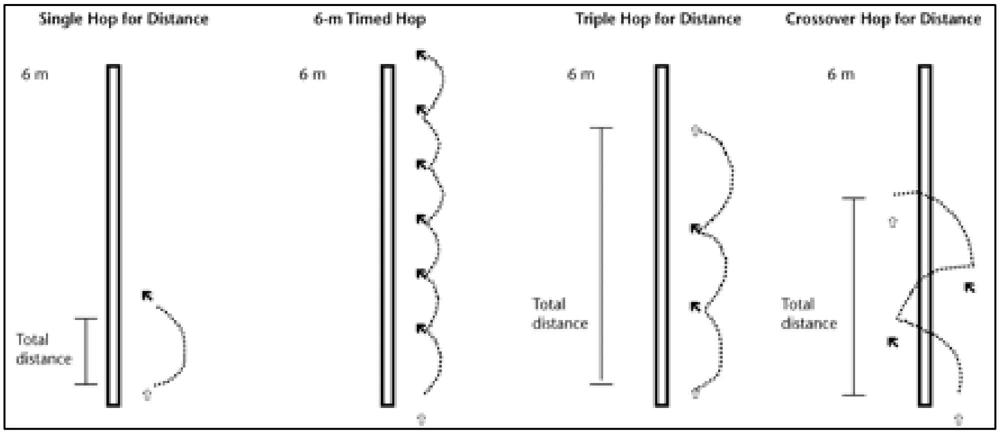

Figure 2: Hop Tests (Reid et al., 2007)

QF Strength Assessment Quadriceps femoris (QF) isometric strength was calculated with an isokinetic dynamometer using isokinetic and isometric testing. In a previous study conducted by (Schmitt et al., 2012), the QF isometric strength test is described in detail. During isokinetic testing, the torque is measured through a range of motion while the limb moves at a constant angular velocity. Subjects sat in the dynamometer with the trunk fully supported with the hips and knees flexed to approximately 90° and 60° respectively. The pelvis and thigh were stabilized with straps while the resistance pad was fastened to the anterior aspect of the subject's ankle. To ensure maximal effort by the participant, visual and verbal feedback were provided during the test. Following one practice trial, three recorded maximum-effort trials were completed for each knee. The participant performed the test at three isokinetic speeds for the quadriceps strength test and two isokinetic speeds for the hamstring strength test. The two speeds for the hamstring strength test were 180°/sec (HS_{180}) and 300°/sec (HS_{300}). The added third speed for the quadriceps strength test was an isometric hold or 0°/sec (QF_{iso}; QF_{180}; QF_{300}). An isometric exercise is a type of training in which the joint angle and muscle length do not change during contraction. Isometric QF peak torque values are routinely used to calculate asymmetry between the involved and uninvolved limbs.

Statistical Analysis Descriptive statistics were calculated for the sample characteristics, total work, hop testing, and strength tests. Linear regression was used to test the association of total work of the involved and uninvolved limb to hop performance and to strength after controlling for height and weight. Alpha was set at 0.05. Height and weight were controlled for in each subsequent regression, which determined the relationship between a predictor and the total work of the subject. Height and weight were controlled for in order to eliminate a confounding variable that could affect the relationship tested. The predictors of interest were the hop test and muscle strength test outcomes. The R^2 and p values were calculated for each set of variables. The strength of each relationship was determined by assessing the R^2 adjusted value which adjusts for the number of variables in the equation. The percent differences between the original model of height and weight and the models including the predictors were calculated.

Results

Descriptive Statistics

Summary statistics for age, clinical hop test and QF/HS strength assessment for the involved (INV) and uninvolved (UNV) limb are presented in Table 1.

Involved Total Work

The total work of the involved limb was predicted solely by height and weight with an R^2 adjusted value of 65.7%. Table 2 provides the results of the linear regression for SHT, THT, CHT, TiHT, QF_{iso}, QF_{180}, QF_{300}, HS_{180} and HS_{300}. Each model shown in Table 2 was significant ($p<0.001$). All predictors were significant except for timed hop (p=0.171), QF isometric (p=0.078) and HS 300 (p=0.631). The predictor for involved total work with the highest R^2 adjusted value was QF 180 (final model R^2=73.8%, p=0.000), with the percent difference from the original model was R^2 change = 8.1% (Table 2).

Uninvolved Total Work

The total work of the uninvolved limb was predicted solely by height and weight with an R^2 adjusted value of 78.9%. Table 3 provides the results of the linear regression for SHT, THT, CHT, TiHT, QF_{iso}, QF_{180}, QF_{300}, HS_{180} and HS_{300}. Each model shown in Table 3 was significant (p=0.000). All predictors were significant (p=0.000). The predictor for uninvolved work with the highest R^2 adjusted value was QF 180 (final model R^2=86.7%, p=0.000), with the percent difference from the original model was R^2 change = 7.8% (Table 3)

Table 1. Descriptive Statistics. Summary statistics for age, clinical hop tests and QF/HS strength assessment.

Variable	**Mean**	**STD**	**Minimum**	**Maximum**
Actual Age (years)	16.956	2.087	13.381	23.397
SHT_INV (cm)	157.44	25.65	94.5	212
SHT_UNV (cm)	166.03	27.03	105	226
THT_INV (cm)	439.5	80.6	286	619.5
THT_UNV (cm)	458.1	87.6	313.5	678.5
CHT_INV (cm)	402.4	80.8	224	602
CHT_UNV (cm)	419.8	86.2	246.5	614.5
QF_{iso}_INV (Nm)	165.9	41.56	72.54	282.55
QF_{180}_INV (Nm)	106.57	32.39	55.32	208.8
QF_{300}_INV (Nm)	82.7	29.47	13.15	172.05
QF_{iso}_UNV (Nm)	184.89	41.92	105.62	336.24
QF_{180}_UNV (Nm)	117.84	33.95	72.54	228.33
QF_{300}_UNV (Nm)	91.23	28.41	45.69	182.63
HS_{180}_INV (Nm)	62.61	19.25	31.18	121.48
HS_{300}_INV (Nm)	55.32	16.71	28.74	101.96
HS_{180}_UNV (Nm)	67.29	22.42	31.05	144.67
HS_{300}_UNV (Nm)	59.44	19.71	32.4	107.65

Table 2. Regression analysis model summary with involved total work as the dependent variable.

Outcome: Involved Total Work					
	Model	**R^2**	**Adj. R^2**	***Difference**	**P-Value**
	Height and Weight	67.0%	65.7%		
Hop tests	Single Hop	73.2%	71.5%	5.8%	**0.002**
	Triple Hop	74.6%	72.9%	7.2%	**0.001**
	Crossover Hop	73.8%	72.1%	6.4%	**0.002**
	Timed Hop	68.3%	66.3%	0.6%	0.171
Quadriceps Femoris	QF isometric	69.2%	67.2%	1.5%	0.078
	QF180	75.4%	73.8%	$\boxed{8.1\%}$	**0.000**
	QF300	70.3%	68.4%	2.7%	**0.029**
Hamstrings	HS180	69.7%	67.7%	2.0%	**0.050**
	HS300	67.2%	65.1%	-0.6%	0.631

*Difference = Adj. R^2_{model} – Adj. $R^2_{\text{height and weight}}$ or the change in Adj. R^2 from the height and weight model.

Table 3. Regression analysis model summary with uninvolved total work as the dependent variable.

Outcome: Uninvolved Total Work					
	Model	**R^2**	**Adj. R^2**	**Difference**	**P-Value**
	Height and Weight	79.8%	78.9%		
Hop tests	Single Hop	84.5%	83.5%	4.6%	**0.000**
	Triple Hop	84.9%	83.9%	5.0%	**0.000**
	Crossover Hop	85.9%	84.9%	6.0%	**0.000**
	Timed Hop	84.3%	83.3%	4.4%	**0.001**
Quadriceps Femoris	QF isometric	81.5%	80.3%	1.4%	**0.041**
	QF180	87.5%	86.7%	7.8%	**0.000**
	QF300	85.4%	84.4%	5.5%	**0.000**
Hamstrings	HS180	83.1%	82.0%	3.1%	**0.004**
	HS300	82.7%	81.6%	2.7%	**0.007**

*Difference = Adj. R^2_{model} – Adj. $R^2_{\text{height and weight}}$ or the change in Adj. R^2 from the height and weight model.

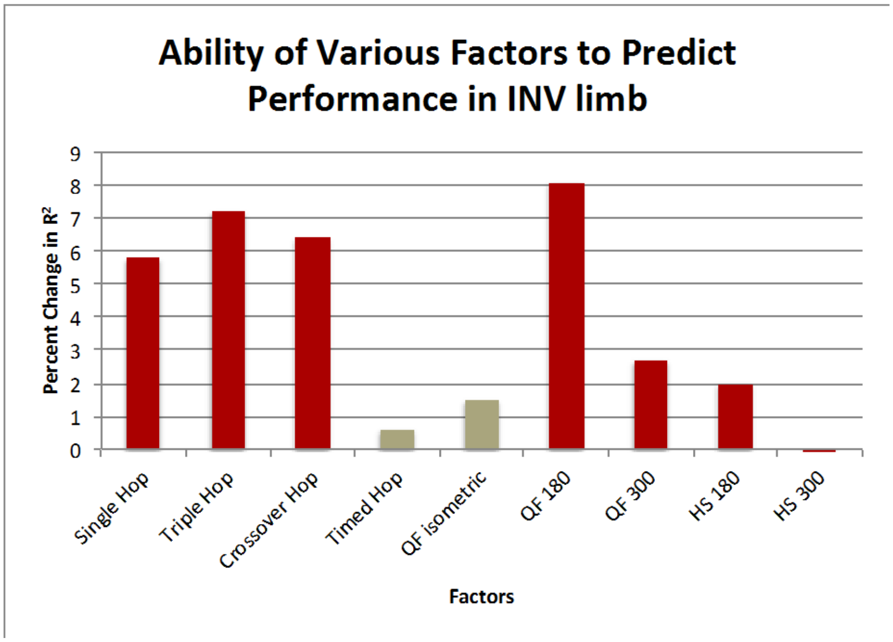

Figure 3. Ability of Various Factors to Predict Performance in INV Limb. Various factors and the percent change in R^2 from the height and weight model in the involved limb. The higher the percent change in R^2, the more variance explained by the factor. The red bars signify that the predictor is statistically significant.

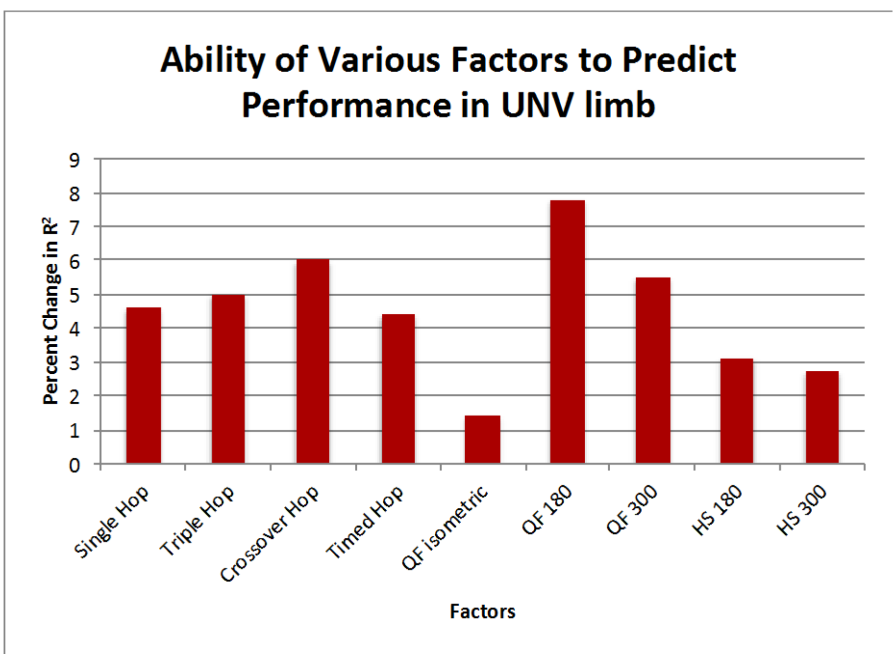

Figure 4. Ability of Various Factors to Predict Performance in UNV Limb. Various factors and the percent change in R^2 from the height and weight model in the uninvolved limb. The higher the percent change in R^2, the more variance explained by the factor. The red bars signify that the predictor is statistically significant.

Discussion

The purpose of this study was to determine the association between measures of hop performance and muscle strength with total work during a single leg vertical jump task in young athletes after ACLR at the time of return to sport. The hypothesis tested was that both the hop tests results and measures of lower limb muscle strength would be statistically significant in predicting measures of total work. The second hypothesis tested was that hop test results would better predict measures of total work compared to strength measures. For the involved limb, various hop test measures and muscle strength measures were significant in predicting total work. For the uninvolved limb, all hop test and muscle strength measures were significant in predicting total work. Both of these results support the initial hypothesis. Of all predictors used, QF180 was shown to be the strongest predictor (highest R^2 adjusted value) of total work for both the involved and uninvolved limb increasing the accuracy of the original model by 8.1% and 7.8% respectively. This result does not support the second hypothesis.

Variables and Expectations

Measures of distance during hop tests and measures of muscle strength have been previously shown to be predictive of functional performance after ACLR (Petschnig et al., 1998; Schmitt et al., 2012). In one study, single-legged hop tests conducted 6 months after ACLR predicted the likelihood of successful and unsuccessful outcome 1 year after ACLR (Logerstedt, Lynch, Axe, & Snyder-Mackler, 2012). The THT has been shown to be a useful clinical test to predict an athlete's lower extremity strength and power (Hamilton, Shultz, Schmitz, & Perrin, 2008). Muscle strength also has the ability to predict functional performance. In one study, preoperative quadriceps muscle strength deficits had significant negative consequences for the long-term functional outcome after ACLR (Eitzen, Holm, & Risberg, 2009). Furthermore, QF strength deficits demonstrated decreased function in individuals post-ACLR and have been suggested to be the best measure of functional outcome in ACLR subjects (Chmielewski, Wilk, & Snyder-Mackler, 2002; Schmitt et al., 2012). Finally, in an additional study, patients with poor functional results have demonstrated reduced muscle strength in the QF compared to the uninjured knee (Schmitt et al., 2012). Based on this literature, the initial hypothesis was generated and was supported through the results of the study.

The secondary hypothesis was generated because previous literature has not conclusively determined the most accurate predictor of total work, or performance, in an individual post-ACLR. Compared to muscle strength testing, single-legged hop testing was predicted to provide a more functional testing alternative because hop testing involves a movement that is critical in many sporting activities. Hop tests are intended to identify lower limb functional limitations. Therefore, the secondary hypothesis stated that hop test results, when compared to other predictors, would better predict measures of total work. Hop tests were hypothesized to be better predictors of total work because they more closely mirrored the repeated vertical jump test which was used to relate to performance. After analysis of the results, the secondary hypothesis was not supported. QF 180, a measure of muscle strength, was shown to be the strongest predictor (highest R^2 adjusted value) of total work for both the involved and uninvolved limb.

In many sports activities, a large, and sometimes unanticipated, demand on knee joint structures and musculature occurs. This demand is typically applied to the QF muscles. One study indicates that deficits in isometric QF strength negatively impact functional performance in young athletes after ACLR (Schmitt et al., 2012). Specifically, the results of the study indicate that isometric QF strength deficits of greater than 15% negatively impact function and performance (Schmitt et al., 2012). The results of the current study align with the results of this previous study. Although many factors other than muscle strength impact functional performance capacity, the results of this study suggest that QF muscle strength may allow for optimal performance during high level activities.

The results indicate that QF180 is the strongest predictor (highest R^2 adjusted value) of total work for both the involved and uninvolved limb, beyond height and weight. QF isometric and QF300, while both significant, have smaller R^2 adjusted values than QF180 and the SHT, THT, CHT (cm). A smaller R^2 adjusted value means that less variance is explained by the particular model. This indicates that the speed is also an important factor in the muscle strength tests. In another study conducted by Wilk et al. (Wilk, Romaniello, Soscia, Arrigo, & Andrews, 1994), a positive correlation was noted between isokinetic knee extension peak torque at 180 and 300 ^{o}/sec and subjective knee assessment scores. This study did not differentiate between the two speeds; however, this positive correlation was not demonstrated at a higher speed of 450^{o}/sec on the isokinetic dynamometer. Wilk et al. hypothesized that if the patient's subjective knee scores were high; they would exhibit less apprehension and would accelerate rapidly without inhibition, thus generating greater torque. These results are consistent with the results from our study.

Height and weight explained more of the variance (higher R^2) in total work for the uninvolved limb than the involved limb. Since height and weight contribute more to the model in the uninvolved leg, this could suggest that an injured limb then causes other factors to become more important and more predictive of performance. For instance, on the involved side, there could be more factors related to the reconstruction or injury that are playing a role in the production of performance. However, QF180 had the highest R^2 value for both the involved and uninvolved limb. This could suggest that QF180 is a strong predictor of performance despite an involved or uninvolved limb.

The repeated vertical jump test was used because it assesses an athlete's ability close to their maximal functional performance. The test's vigorous jumping task assessed over duration of time allows the test to be reflective of maximal functional performance. In fact, the one-legged vertical jump is sensitive enough to detect functional limitations of the lower limb following knee ligament reconstruction (Petschnig et al., 1998). The vertical jump provides an assessment of strength, power and the patient's willingness to accept weight on the lower limb. The assessment of lower limb function encompasses many variables including neuromuscular coordination and strength. This test is more demanding and provides more useful information to a clinician than a simple jump or muscle strength test. The repeated vertical jump test mimics functional demands of sports such as soccer and basketball. Functional demands are tasks that involve simulation of direction, force production, type of contraction and dynamics of a certain movement. For example, a movement could be an explosive concentric contraction or a slow eccentric contraction. The clinician's main goal of rehabilitation for athletes is to return the athlete to maximal functional capacity instead of a low daily functioning level. The repeated vertical jump test has been shown to be a good indicator of this ability which is why this test was used to quantify performance in this study.

The repeated vertical jump test, while a valuable test, requires the use of a force plate in order to generate data on total work of the athlete. The equipment demands of this test necessitate the use of a sports medicine biomechanics research lab and is, therefore, not able to be performed in a clinic. To find a factor that best predicts total work and can be measured in a clinical setting was the ultimate goal. The hop tests and muscle strength tests were chosen to predict performance on the repeated vertical hop test because of their clinical utility to assess functional performance capacity and dynamic neuromuscular control mechanisms in a controlled manner during activities that challenge knee stability and mimic the greater demands imposed on the knee during higher-level activity (Schmitt et al., 2012).

Return to Sport Criteria

Performance is a measure of one's functional capacity as it relates to success in a certain endeavor. In this study, athletic performance is of particular importance. Maximizing functional capacity involves the athlete's ability to demonstrate certain physical and psychological characteristics as determined by his or her sport. Most authors advocate resolution of impairments and adequate functional performance, evidenced by clinical milestones to indicate readiness to return to sport after ACLR (Schmitt et al., 2012). However, as previously mentioned the criterion value indicative of readiness for sport participation varies widely and is not empirically based. Based on the results of this study, QF180 strength assessment can be used as a strong predictor of one's total work during a jump task or overall jumping performance. QF180 is an empirically supported strong predictor of an athlete's performance which should be a focus in rehabilitation and evaluated for determination of rehabilitation completion and return to sport. This addition to the return to sport criteria would provide a more promising outcome for athletes by ensuring enhanced performance capability upon return to sport.

Study Limitations

The use of the repeated vertical hop test as a measure of performance is an approximation. The accuracy with which this predicts functional performance has not been empirically shown. However, a measure that correlates with performance is needed in order to assess this ability in a clinical setting. While QF180 was shown to be a strong predictor of total work, there are many potential contributing factors beyond QF muscle strength that impact function and performance that this study did not address. Additional studies have indicated the importance of hip and trunk muscle strength and activation in order to achieve lower extremity control and proper knee biomechanics (Schmitt et al., 2012). Lack of hip and trunk muscle control has been associated as a risk for both initial ACL injury and second ACL injury following ACLR and return to sport (Paterno et al., 2010). Our study did not explore measures of hip and trunk muscle strength, which could potentially affect overall function and performance after ACLR. Additionally, motion data was not collected along with the force plate data. Motion data would have provided the ability to detect the source of energy generation in the athlete.

The ratio of males to females in the sample group was skewed, but sample size limited further analysis of the influence of sex on the study. All male and female results were grouped together which eliminates the ability to determine if differences in sex impact results. In addition, all participants were young, active individuals, which impact the generalizability to other individuals after ACLR. QF strength deficits on functional performance may be applicable to a larger population following ACLR when establishing achievement of adequate functional capacity and physical therapy discharge criteria.

Future Research

Future research is needed in order to compare power absorption and generation in the athletes. Dissipation and generation of energy are important factors in injury prevention and performance measures. Further research is also needed to utilize a motion analysis program in order to capture the source of the work done by the athlete. Motion analysis can calculate the work done at each joint. Finally, sex differences should be evaluated and sexes studied separately to determine if sex influences the results of this study. For instance, jumping patterns and the total work performed by the athlete could differ based on sex.

Conclusion

Various clinical measures of hop and muscle strength test performance, in this study, were shown to have a strong correlation with power output during a demanding repeated vertical single leg hop test. Power output was equated to total work and depicted performance capacity of the various athletes. QF180 was shown to be the strongest predictor of total work for both the involved and uninvolved limb increasing the accuracy of the original model by 8.1% and 7.8% respectively. Future research is needed to determine a causal relationship between performance on the repeated vertical single leg hop test and sport performance after ACLR.

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Resources

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